FOAMING OF ALUMINIUM WITH AND WITHOUT TiO_2 ADDITION

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Abstract: A study was carried out into the formation of aluminium foams via powder processing route. Aluminum powder compacts both in pure form and Al-5%TiO_2 were foamed at temperatures ranging from 675 to 800°C. Foaming agent TiH_2 was mixed with powders typically with 0.6 wt % in two different sizes. Experiments have shown that foaming in excess of 120 % is possible both with pure Al as well as in Al-TiO_2. It is found that with coarse TiH_2, with and without TiO_2, Al expands more, implying that there may be a certain size below which particles may not participate in the foaming process. It is further found that with the use of high temperature there are internal reactions between foaming agent and aluminium as well as between TiO_2 and Al. This is with the result that with TiO_2 added system foaming becomes more temperature dependant than the pure Al.

Key words: Aluminum foam, powder processing, foaming agent size, TiH_2, TiO_2, macrostructural control.

1.INTRODUCTION

In recent decades there has been much emphasis on lightweight materials and structures. Therefore metallic foams together with other cellular materials are becoming an important group of materials within themselves. In addition to their lightness, metallic foams have additional properties such as energy absorption, heat insulation etc.

Metallic foams can be produced with a variety of techniques [1]. Of these, foaming, based on powder processing is quite common [2]. This typically involves mixing of a suitable foaming agent with metallic powder, followed by compaction and finally foaming. Aluminium and its alloys due their already low density are particularly attractive for foaming. Foaming agent is normally titanium hydride (TiH_2) that decomposes at temperatures above 550 °C.

Foaming of aluminum in its pure form is not very common. Normally it is necessary to add some additives such as nitrides, carbides and oxides that act as stabilizing agent. These additives may be added as they are or may be formed in situ as is the case with Ca addition to form CaO [3]. In the case of alloys, such additions may not be necessary since, when foaming is carried out between solidus and liquidus, the solid fraction that remain in the system may act as stabilizing agent. As reported by Webben et al.[4],stabilizing agent contributes the foam stability by three possible mechanisms: by increasing viscosity, by decreasing surface tension, by delaying liquid film rupture. Various systems [5-8] have successfully been foamed e.g. AlSi, AlCuMgSi AlSiCu and AlMgSi

The current work uses TiH_2 in two different particle sizes and examines the foaming of aluminium with and without stabilizing agent, i.e.TiO_2. Emphasis is on structural changes that occur during foaming which may be important so as to exercise control over the process.

2.EXPERIMENTAL PROCEDURE

Powders used in this study were Al (27 μm) and TiO_2 (<1 μm). TiH_2 ,44 μm in size, was used as foaming agent. To examine the effect of TiH_2 size on foaming, it was ground to below 5μm via ball milling for 24 hours with ball to powder ratio 10:1

Table 1: Systems for Foaming

System	Temperature of Foaming
Al - unmilled TiH_2	675°C & 725°C
Al - 24 hrs milled TiH_2	675°C & 725°C
Al - unmilled TiH_2 - 5 wt % TiO_2	750°C & 800°C
Al - 24 hrs milled TiH_2 - 5wt % TiO_2	750°C & 800°C

Metal powders of composition specified in Table 1 were dry mixed for one hour with a shaker (ball to powder ratio: 1/2). Powders were subsequently consolidated by hot swaging at 400°C. This temperature was selected based on desorption tests at which there was no noticeable hydrogen release from TiH_2. For swaging, mixed powders were enclosed into a copper tube of 22 mm in diameter and hot swaged down to 6.6 mm.
Swaged samples were cut into pieces approximately 10 mm in length for foaming experiments. Foaming was carried out in a preheated vertical tube furnace in which temperature were controlled with ± 5 °C. For pure systems, foaming temperatures were 675°C and 725°C, and with TiO_2 addition, 750°C and 800°C.
Volumes of sample before and after foaming were measured by Archimedes principle and the change was used as a measure of foaming.

3. RESULTS AND DISCUSION

Typical macrostructures of as swaged powder compacts are shown in Figure1.The micrographs were recorded in backscattered mode and therefore TiH_2 and TiO_2 where present appear bright. Structure as seen in longitudinal section indicate that swaging leads to a good consolidation of powders, Figure 1(a) Samples with TiO_2 addition when examined at transverse section shows a cloud like distribution, Figure 1(b). Thus, TiO_2 which had extremely fine size (< 1μm) could not be homogenously distributed among Al powders. Agglomerated TiO_2 particles enclosed within Al powders, see Figure 1(a), are distributed into the cloud like morphology given in Figure 1(b) as a result of swaging deformation.
Structural examination on as swaged samples showed that there are instances of particle cracking in consolidated samples, Figure 1(c). Thus, there is some degree of TiH_2 size reduction during swaging, especially for coarse TiH_2 addition. Such observations have also been reported in other similarly deformed heterogeneous systems [9]. With coarse TiH_2 addition, swaged samples show a distribution of TiH_2 sizes up to 50 μm. With fine TiH_2 additions , the sizes are normally in the order of 2-3 μm and occasionally can reach sizes up to 10 μm
Results of foaming experiments for pure aluminium carried out at 675°C and 725°C are given in Figure 2(a) and (b) respectively. A value of approximately 120 % foaming is achieved at both temperature.
An example of foamed structure is given in Figure 3 ,where region in between the pores show a well-defined solidification structure with embedded bright "TiH_2" particles. Whether these particles are TiH_2 or Ti, i.e. they released their hydrogen, could not be determined. It is interesting to note that "TiH_2" particles observed in-between the pores are not as large as those observed in the original swaged samples. A careful examination on the sizes of "TiH_2" showed that although there were few exceptions, the particles were mostly of sizes close to or less than 10-15 μm.
At 725°C, there is clear indication of internal reaction between the host and added particles. Figure 4 shows originally TiH_2 particle feeding a pore at one of its edge, partially transformed, verified by local elemental analysis, into Al_2Ti.

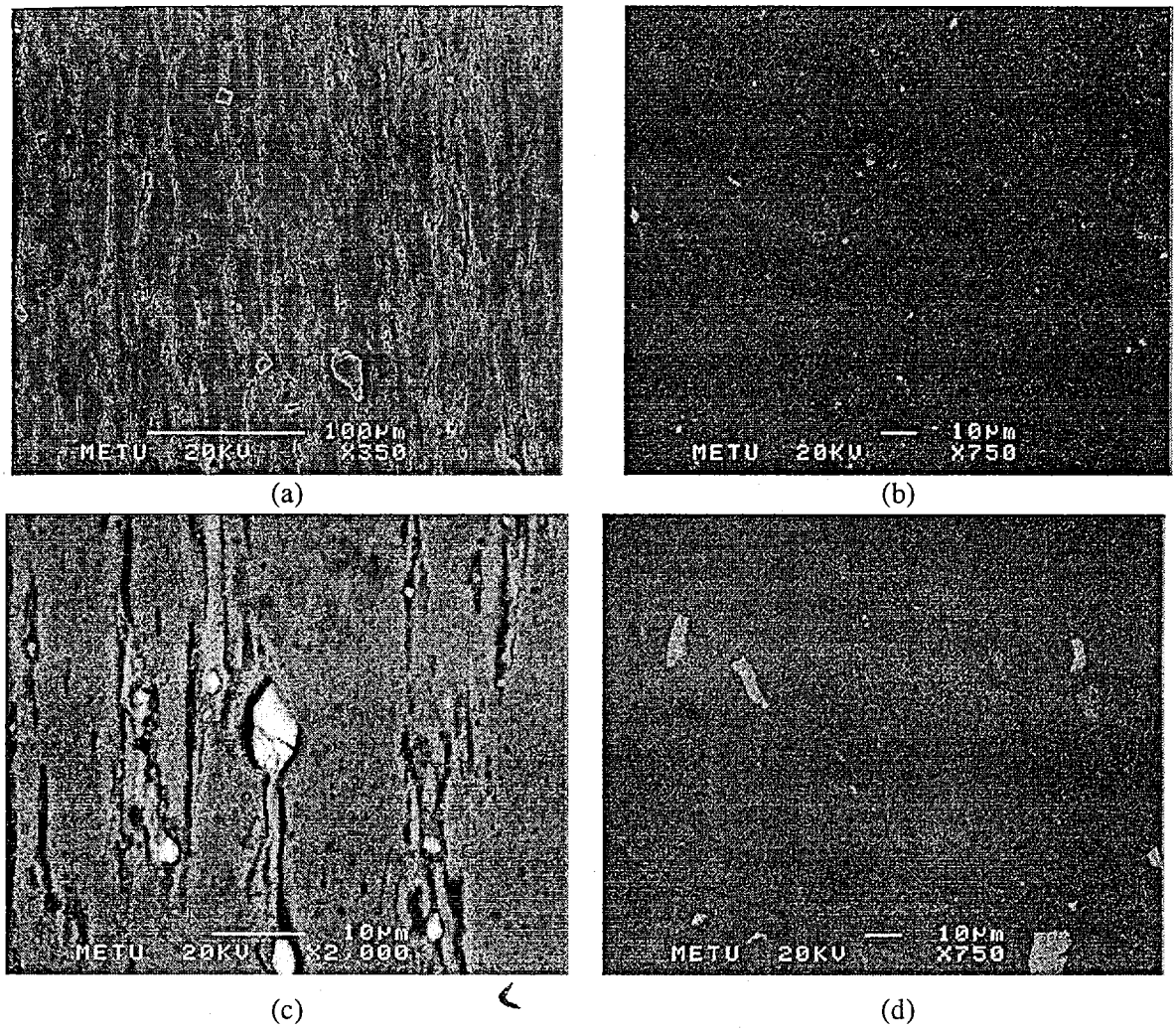
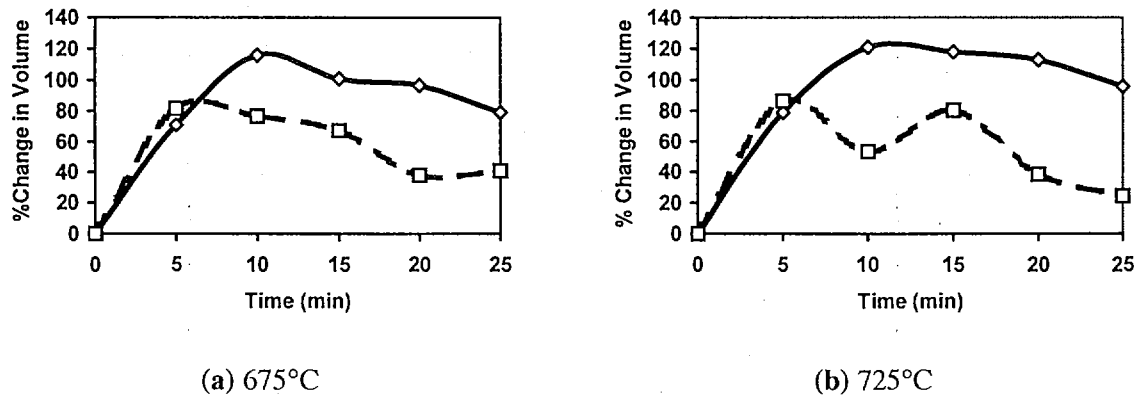


Figure 1. Macrostructures of Al-5 wt% TiO_2 in swaged condition. Ti containing phases, i.e. TiO_2 and foaming agent TiH_2 appear bright. (a) and (c) refer to longitudinal , (b) and (d) refer to transverse cross-section. Note cracking of TiH_2 in (c)



(a) 675°C (b) 725°C

Figure 2. Foaming in Al containing either coarse(solid) or fine(dotted) TiH_2 , see text for details. a) at 675°C and b) at 725°C

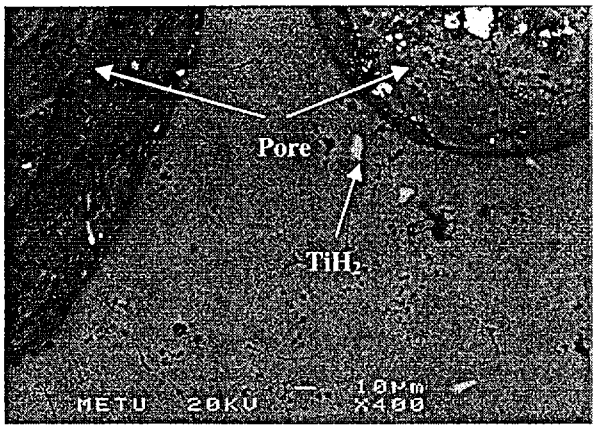


Figure 3. Structure of Al, foamed at 675 °C. Note Ti rich particles close and away from pores

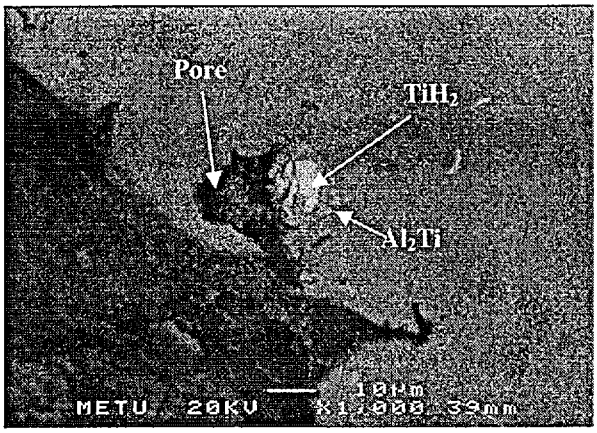
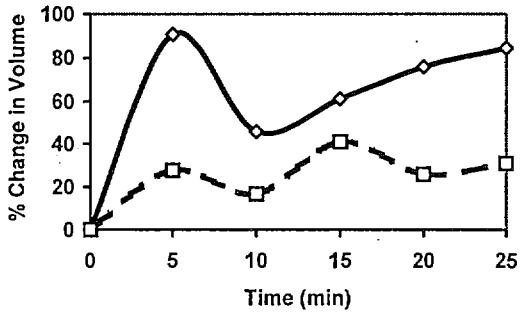
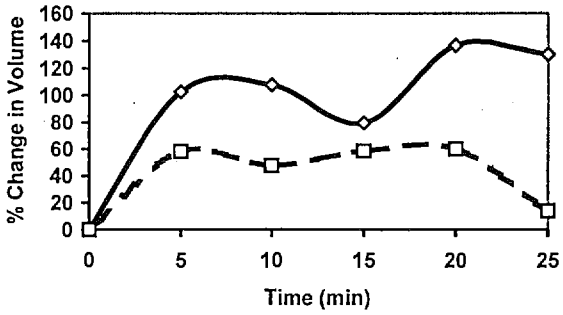


Figure 4. Structure of Al, foamed at 725°C. Note Ti rich particle at a bay of a pore.

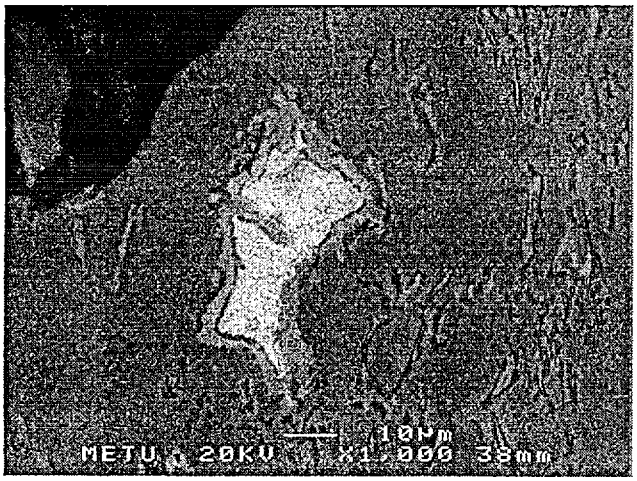


(a) 750°C

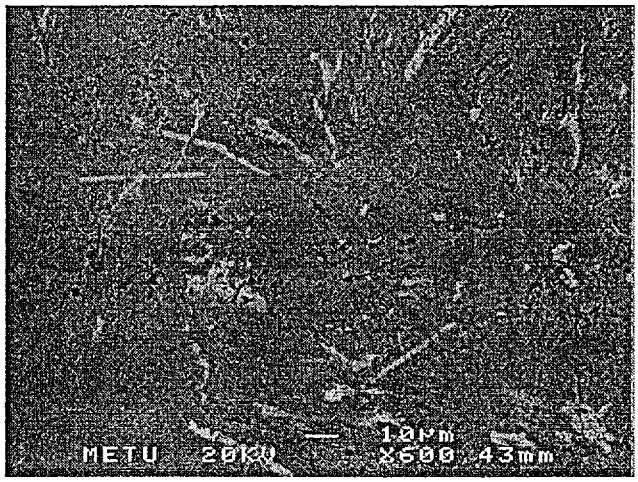


(b) 800°C

Figure 5. Foaming in Al - 5wt% TiO_2 containing either coarse (solid) or fine (dotted) TiH_2, ,see text for detail . a) at 750°C and b) at 800°C



(a) 750 °C



(b) 800° C

Figure 6. Structure in Al-5wt% TiO_2. a) 750° C . Note gray(intermetallic) region enveloping bright Ti particle. b) 800° C, note that all particles appear gray

Samples with TiO_2 addition required much higher temperatures for foaming. Thus, foaming experiments were carried out at 750 and 800°C. Results are reported in Figure 5. Unlike the case of pure Al reported above, the temperature of foaming produces a pronounced effect on the degree of foaming achieved.

Structural examination showed that there are pronounced internal reactions at these temperatures; particles of originally TiH_2 or TiO_2 compositions were partially or totally transformed into intermetallics of Al and Ti. An example of partial transformation is given in Figure 6 that refers to 750°C and that of complete transformation at 800°C in Figure 6(b).

In samples foamed at both 750 and 800°C, there is no clear evidence for the presence of TiO_2. This is also probably due to internal reaction between Al and TiO_2. It is well known that the two constituents react with each other starting from approximately 600°C giving rise to formation of TiO and Al_2O_3. According to Feng and Froyen [10] at temperatures above 700°C TiO further reacts with Al producing the same Al_3Ti. Thus TiO_2 added system is much more complex than that of pure aluminium. These complex internal reactions changes the solid content of the system and thus its viscosity in a manner that is dependent on temperature (as well as on time). This is probably the reason for the temperature dependant behavior of TiO_2 added systems in foaming

4.CONCLUSION

With the current investigation into foaming of Al with the use of TiH_2 the following can be concluded;

1- TiH_2 particles of less than a certain size do not seem to participate in the foaming process. The existence of such critical particle size require further investigation.
2- Especially at high temperatures, foaming agent and Al matrix react with each other giving rise to the formation of high melting point intermetallics. The formation of such intermetallics modifies the viscosity of the liquid and thus may affect the foaming process.
3- With respect to selection of additives, The possibility of internal reaction between the additive and the host, , should be taken into account which can lead to greater volume fraction of solid content and thus greater viscosity than that aimed for, as is the case with TiO_2 .

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